Research and the War Effort

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TO a democracy, nothing is more important in the conduct of a war than the working out of smooth relationships between civilian organizations and military organizations in all aspects of the war effort. I wish that I might go into this broad subject at length, but in this discussion I must confine myself to one phase of the matter, namely, the relationship between scientists and engineers and the military services in connection with the development, production, and use of weapons.

The relationship between scientists, engineers, and the armed services in the development, production, and use of weapons is of great importance in meeting the exigencies of war, says the director of the Office of Scientific Research and Development, an agency charged with co-ordinating the efforts of technical men to evolve instruments of war in collaboration with the Army and Navy. The interrelated work of this and other agencies, which are concerned with development rather than procurement, is contributing toward filling the vast need of the armed services for the adaptation of war implements to changing conditions.

No one can read the accounts coming back from the battle fronts without recognizing that it matters a great deal what sort of weapons we are using and what skill we employ in their disposition. It is not sufficient to be possessed of good weapons; it is essential to be possessed of weapons that are better than those in the hands of the enemy and to use them with greater skill. The attainment of this objective involves the closest sort of collaboration between military men on one hand and civilian scientists and engineers on the other, and it is a part of this relationship that I propose to trace. It is well, I feel, that we should study carefully into this relationship, not only because it is essential to our effectiveness in this war, but also because I hope and trust that the lessons we are learning currently will not be forgotten when we again return to peace.

CIVILIAN COLLABORATION WITH ARMY AND NAVY

One of the advantages of a democracy is that when it is engaged in a war, no one feels that everything should be controlled by the military. There are great areas where civilian organizations can operate to better advantage, and this is and has been our accepted policy. The joints may creak at times, and there is bound to be confusion simply in view of the enormous magnitude of the job involved, but in general we get along faster when civilian organization produces the weapons with which the Army and Navy fight. The same advantages may be cited for civilian research and development, collaborating closely with the armed services, and meeting their needs as far as is physically possible, but acting with that flexibility and freedom which come from independent organization.

I believe, and I know that I am joined in this belief by most of the men with whom I have worked closely in the past three years, that we have gotten on more rapidly and more effectively during this present war in the development and introduction of new weapons under the form of organization whereby civilian groups supplement the work of the Army and Navy than we would have had the entire affair been closely under military control. There are many reasons for this. One of them is the fact that the Army and Navy are exceedingly busy with the immediate. It would be difficult indeed for a military organization to provide adequately for the long range view while at the same time carrying its enormous responsibilities in regard to the battle which may come in the next few months.

I feel sure that new and valuable ideas are much more likely to come to fruition if they can develop their formative stages among groups of independent scientists and engineers before being subjected to the rigors of military association. We are engaged with skillful and resourceful enemies, and we should not at any point underestimate them. Germany in particular has too long a history of scientific and technical accomplishment for us to be tempted to underrate its possibilities in applying its skill to the conduct of war; and Germany has been fully engaged in the development of war techniques for a much longer time than have the democracies. Nevertheless, I believe that the present rigid military regime in Germany is at a disadvantage, when it comes to the development of really new ideas, as compared with the United States, with its ingenuity and resources; and I believe that is especially true in view of the fact that the organization under which we operate gives full rein to the independent efforts of some of the finest scientists and engineers that the country has produced, under conditions in which they can work substantially in their own way and in accordance with their chosen methods, but toward a common end.

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But a democracy in wartime has certain handicaps also. Unfortunately, from one point of view, our own country has a striking difficulty in adapting itself to modern war which is not generally realized. We are a people who think in terms of mass production. This is excellent, and it constitutes one of our greatest factors of strength. It has, however, the distinct liability that we are likely to think in terms of freezing of designs and production of great masses of standardized equipment, and we think much less readily in terms of a rapidly changing technical situation. In modern war it is a serious thing to be inflexible in this regard.

The weapons that are being used are continually changing. Some years ago I used to meet military men who took the point of view that once war was entered upon the fighting would have to be done by utilizing the instrumentalities available at the beginning of the conflict. I have not heard this view expressed for quite a long while now. Every phase of warfare is changing and is changing radically, and the change is coming about primarily because the methods used are vastly different. The central problem, therefore, in the effective conduct of the war from this standpoint is to be sure that our weapons are thoroughly up to date. This involves a long chain of endeavor, beginning with scientific research and engineering development, and proceeding through tests, procurement, installation, and the training of personnel, to the final use in combat. If any one of these steps is not thoroughly and carefully taken, the end result will not be sufficient.

But the process must be swift also, and mass mindedness is a dangerous state for us unless we also keenly realize its dangers.

Under ordinary peacetime circumstances the progress from a brand new idea to its use in quantity by the public occupies at least five years. There has to be research, development, and engineering design. There has to be design for production and user experience obtained under carefully controlled conditions. Out of this can come a well-engineered device adapted for production in quantity to meet a mass need in an economic manner. Under ordinary peacetime conditions a company that is introducing a new product will short-circuit this proper and deliberate method at its peril, for large indeed are the penalties of plunging into quantity production before all of the loose ends are tucked in. Yet in time of war we are faced with the dilemma of shortening this process or else being dangerously behind the times. Under the stress of war it is possible to compress the time scale somewhat. If it is compressed too much and proper engineering is not accomplished, the results may be very sad. On the other hand, delay in getting new devices into operation in time may have consequences that are disastrous. The attainment of a proper balance in this regard is one of the most difficult problems confronting the industry that produces the devices and the military groups that utilize them. I feel that on the whole we have done a remarkable job of attaining a just balance, but I do wish to emphasize strongly that the matter can never receive too much consideration and attention in a country such as ours, where all our normal peacetime habits lie along the lines of standardization and large-scale production.

FORMATION AND FUNCTION OF THE OSRD

In the progress of a new weapon, from the first idea, to the final use, engineers and scientific men of professional grade enter at many points. Notably they appear as a part of the personnel of the armed services themselves, and they appear also in industry in the manufacture of equipment, and also in those services which are auxiliary to manufacturing effort, but none the less essential if the whole scheme is to function adequately. I shall not attempt to trace all aspects of this matter by any means. I feel, however, that it will be worth while to trace the phase that is concerned primarily with the development of the new weapon from the standpoint of the governmental organization which has been charged with this responsibility in this present war.

It is now nearly three years since the scientists and engineers of this country were organized under governmental auspices for the development of new weapons. In June 1940 there was formed the National Defense Research Committee, charged by the President with the duty of research and development on new weapons and instruments of war. The initial organization was relatively small, but it has grown to a considerable scale. In June 1941 a reorganization occurred and the Office of Scientific Research and Development was formed by executive order. The OSRD was given the broad task of co-ordinating the efforts of scientists and technical men in connection with many phases of the war effort, but it was also given the definite charge of pursuing aggressively the work that had already been started by the NDRC; and for this purpose NDRC was incorporated into its organization. At the same time OSRD also was charged with the carrying on of medical research which is closely associated with the prosecution of the war, and it does so through the efforts of the Committee on Medical Research which is a part of its organization. The entire history of this medical effort is well worth the telling.

At the present time the OSRD is making expenditures at the rate of about $100,000,000 a year. In terms of the over-all war cost this is not a large amount of money. It is, however, a substantial sum when considered in terms of research and development. The OSRD operates entirely by contracts with existing academic institutions, industrial organizations, and government agencies. This method is designed to utilize to the utmost available facilities and personnel and to avoid, as far as it can be accomplished, the construction of great new laboratories. About 2,000 contracts for the carrying on of research have now been entered into and of these about

1,400 are currently active. Approximately 200 industrial laboratories and 100 colleges and universities are at work on OSRD projects, and the number of men involved of professional grade is in the neighborhood of 6,000. These men have assistants of various types.

The way in which the organization functions will, I think, be of interest. There is the closest sort of interrelationship with the Army and Navy at all levels. The NDRC is broken down into 18 major divisions concerned with various phases of war research, and in many cases these in turn are subdivided into sections. Each section is composed of scientists and engineers who are specialists on some phase of the enormous range of war instruments. Working closely with them are officers from the Army and Navy who are also specialists in the field concerned, but who bring in addition the war experience and the contact with tactical reasoning which is essential for sound planning.

The research projects arise in these sections, usually by reason of round-the-table discussion of the current situation and the needs for improvement. Out of such discussions comes usually a definite request from either the Army or the Navy that the OSRD undertake a development along a certain line. The section is charged with the duty of finding the best laboratory for the conduct of the work and the best personnel to carry it on. After these considerations have been met, the section then recommends a contract for the accomplishment of the work. This recommendation is reviewed by the NDRC, and if the committee approves, it passes the recommendation together with its endorsement to the director, who authorizes the work to proceed.

The NDRC examines the operations of divisions through the medium of small subcommittees, and by bringing before it the chiefs of the several divisions.

The manner in which the NDRC operates in this connection is of great importance since it is the central reviewing agency which ties together the entire program. Doctor James Conant, president of Harvard University, Boston, Mass., is the chairman of NDRC, and its members are as follows:

Doctor Roger Adams, head of the department of chemistry of the University of Illinois, Urbana; Doctor Karl T. Compton, president of the Massachusetts Institute of Technology, Cambridge, Mass.; Doctor Frank B. Jewett, president of the National Academy of Sciences; Doctor Richard C. Tolman, dean of the graduate school of the California Institute of Technology, Pasadena.

These are the men who primarily represent American science and engineering. The Honorable Conway P. Coe, commissioner of patents, is also a member and brings to the committee his wide knowledge of inventions and their appropriate handling. The Army is represented by Major General C. C. Williams, whose office in the Services of Supply is in touch with developmental work throughout the Army, and is also in touch with the needs of the Army. Captain Lybrand P. Smith represents the Navy Department, where he serves in the Office of the Co-ordinator of Research and Development.

Once a project has been authorized, the office of the chairman of NDRC is charged with the duty of administering the project from its scientific and technical standpoint. For this purpose the line of authority flows from the director, through the chairman of NDRC, to the divisions, and members of these divisions become the authorized representatives of the office in the guidance of the contractors in their scientific and technical research, in order that their efforts may be directed along the lines that have been approved by NDRC as best adapted to the needs of the services. In this way also adequate reports of progress are made available promptly to the interested parties in the services.

Since the OSRD is concerned with many broad aspects of the relationship between the military services and the civilian organizations, the director of OSRD also has the benefit of an advisory council, which is representative of many points of view. The council comprises:

Harvey H. Bundy, special assistant to the secretary of war; Rear Admiral J. A. Furer, co-ordinator of research and development of the Navy; Doctor James Conant, representing the NDRC; Doctor A. Newton Richards, chairman of the Committee on Medical Research; and Doctor J. C. Hunsaker, chairman of the National Advisory Committee for Aeronautics.

It has also recently included in its discussions Doctor Harvey N. Davis, director of the Office of Production Research and Development of the War Production Board. By special direction of the President, the director of OSRD has the benefit also of the advice of the president of the National Academy of Sciences, who joins in many council deliberations. All of these various organizations will be mentioned later, for their interrelation in the technical phases of the war effort is of much importance.

To continue, however, with the actual functioning of the OSRD, I wish to mention several other phases of its activities and some of the problems that it has faced. The business affairs, concerned with contracts and the like, are handled by the executive secretary of OSRD, Doctor Irvin Stewart, who also conducts relations with other governmental agencies on financial and legal matters.

It has been a task of no small magnitude to fit the OSRD into the framework of the government, so it could operate in a smooth and effective fashion. The office is a part of the Office for Emergency Management, which is in the executive office of the President. The OSRD has attempted, and I believe with extraordinary success, to carry on its affairs strictly within the framework as laid down by Congress, and in accordance with the regulations for the conduct of government business with which these various agencies are charged.

Throughout the rapid growth of OSRD it has had exceedingly effective support from all of the agencies with which it has necessarily come into contact, notably with the Bureau of the Budget, the General Accounting Office,

the Civil Service Commission, and many other groups with which it is concerned as an independent agency within the executive office of the President. It is a pleasure to report that in two and one-half years of experience as the head of a new and vigorous government agency, I have never met with anything but the most helpful attitude on the part of the agencies with which I have been called upon to deal, and with the committees of Congress that have had to do with the affairs of the office. This has been in no small degree due to the excellent support of the executive secretary and his office.

The organization includes also a liaison office, reporting to the director, and charged primarily with the duty of conducting appropriate technical interchange with the allies of the United States. Under specific instructions from the President, there was instituted very early a close interchange with the British on technical matters, and this relationship has continued in a cordial and effective manner. I feel sure that this interchange has expedited the work of scientists and technical men in England in their magnificent efforts for the protection of the British Isles, and I am sure that it has benefitted the United States in its war effort. The liaison office, under Doctor Caryl P. Haskins, maintains a London office through which there are contacts with the British Government at all times.

The close interrelationship of science and engineering is essential in the early aspects of the development of a new weapon. The divisions of NDRC accordingly are made up of men chosen from both fields, working closely in collaboration. Incidentally, these men are selected both from universities and from industry, from large colleges and small colleges, and from private laboratories, and they are drawn from all over the country. Many of them serve without remuneration on a part-time basis; others are on the government payroll, while on leave of absence from their organizations. They serve in every case, of course, as individuals, and they are chosen for their individual qualifications.

In the introduction of a war weapon into use there is, however, a special problem which is unique and which is not encountered in the same form by industry in the course of its development of new devices. During the course of the introduction of a new weapon it passes from the hands of OSRD directly into the hands of the armed services. OSRD is charged with the research and development, but it is not charged with procurement and use, which are in the hands of the armed services themselves. The armed services themselves directly and through contract carry on a great deal of research and development, and many of their new devices come through this channel. This again I will mention later. However, at the present time I wish to trace the handling of the problem which occurs by reason of the transition of devices from the laboratory into the hands of the military. In order to co-ordinate this aspect of its work, NDRC maintains two special pieces of organization. One is what is called an engineering panel, made up of engineers who are at the same time members of the various divisions, together with certain other engineers chosen for their over-all grasp. This panel is charged with the duty of seeing to it that appropriate engineering skill is made available to the divisions and sections in an effective way at such time as a new device approaches the period in its development where it begins to be adopted for actual production and use.

The other special piece of organization is the so-called transition office, which is charged with the responsibility of following the progress of devices, in order to make certain that the problem of scarce and strategic materials is considered in sufficient time. The transition office also arranges with the armed services for initial production in order to carry the device through the transitional phase, in which it has emerged from the laboratory but has not yet appeared in quantity. At this point there is usually involved the production of a sufficient number of pieces of equipment, often produced by hand methods, for purposes of extended tests in the field. There is involved also the selection and indoctrination of an appropriate manufacturer.

CONFIDENTIAL WORK OF THE OSRD

In order to appreciate the way in which the OSRD operates, it is necessary to realize that practically everything it does is highly secret, and that it is not possible to carry on its work under conditions of great secrecy with the same dispatch which is possible when no such conditions obtain. For reasons of security, appointment of personnel in any capacity throughout the organization is made only after careful investigation. A ruling principle, and one which is observed by the Army and the Navy, is that secret matters are held carefully in compartments. This means that no member of the organization will learn of secret matters except to the extent that is necessary for his appropriate functioning in the particular position which he occupies in the organization. Knowledge concerning especially secret matters is restricted to decidedly small groups within OSRD and within the services themselves.

This leads me to mention one other matter. Ever since this organization was formed, I have encountered the question many times as to why it needs to be organized on a national and vertical basis in accordance with subject matter, and why it cannot be decentralized geographically to obtain the benefit of the many individuals in the country who are highly capable in technical ways, but who must necessarily operate on matters of the war effort in their own localities. The necessity for secrecy and compartmentalization is the reason. In many cities in this country, it would be quite possible to form very strong technical and scientific groups locally, composed of men who would put in part of their time, in the evenings and on week ends, on technical matters connected with the war. These groups could represent

many sciences and many types of engineering, and they would be made up of decidedly effective individuals. However, this scheme is not compatible with necessary restrictions on the work of OSRD. It would hardly be possible to assign one subject to each group in a locality. Neither would it be possible to give to such a group the knowledge of the entire range of the development of weapons which would be essential in order to use effectively the diverse characteristics such a group would have. Hence we have felt reluctantly that such groups could not be utilized in the affairs of OSRD. I do feel, however, that they could have real value in other connections, where the conditions of secrecy are not nearly so stringent, and this possibility is being explored.

On the other hand, while OSRD is organized nationally, drawing its membership from all over the country, its sections are made up of men especially adapted for the problems before them and these men are given full knowledge of the technical and tactical phases of the particular weapons with which they deal. They are kept closely in touch with the progress being made in introducing weapons of this particular type in practice, and they form teams which are able to enlist the services of large numbers of men in many universities and industries for the accomplishment of their purposes. All this is done in such a manner as to keep the secret information as closely confined as is consistent with rapid progress.

As previously mentioned, not all of the research and development on weapons in this country is carried on by OSRD. It is the duty of OSRD to relieve the armed services as far as possible in this regard, and indeed as the war proceeds and as the officers in the services become more and more burdened with immediate matters concerning the conduct of the war, the load in regard to research and development has shifted quite naturally, so that OSRD is carrying a greater share of the burden. However, both armed services maintain large laboratories in peace and in war for the development of weapons, and they also further development by direct contract with industry.

The mention of this matter gives me an opportunity to state definitely a fact on which I think there is a great deal of misunderstanding. It has been publicly known for a long time now that when Germany started its all-out air attack on Britain in the summer of 1940, the attack was repelled not only on account of the magnificent equipment and fighting qualities of the Royal Air Force, but also because the British had and effectively used certain radio-warning devices which took the surprise out of the Germans' attacks and assured that their bombers were promptly met by fighter squadrons. It is also known that the British had this device because of the effective work of a group of British scientists and engineers over a considerable period of time. I am also very glad to be able to state that at the same time the Army and Navy of the United States had equally effective devices for this purpose, well developed and in hand. This had been accomplished during years of peace, in spite of the fact that the United States had failed to support its military departments to an extent which rendered research and development in peacetime possible on anywhere near an adequate scale. In particular, I know personally of the early work in this field by a small group of keen naval officers, and there were undoubtedly other groups at work elsewhere. I am looking forward to the day when due tribute can be paid to those officers who very early saw the possibilities of devices of this sort and worked assiduously to the end that they might be practically available. I also wish to emphasize strongly that this work was done long before Europe went to war, still longer before there was any such thing as NDRC. Certainly since its advent, NDRC has worked along these same lines. It has been proud to collaborate with the Army and Navy in so doing, and to work in partnership for the further development of devices on which they had already pioneered, and to share in all of the various possibilities flowing out of that early work. The full story of this development, when it can be told, will involve many scientists and engineers, and its roots go far back for many years. At the present time we are altogether too busy to think much about credit.

RECEPTIVITY TO CHANGE

This leads me to a statement that I have pondered for some time. I am occasionally met by the old accusation that military men are hidebound and reactionary, and that they are generally resistant to the introduction of new ideas. As applied to the present Army of the United States, such a statement is of course absurd on its face, since 24 out of 25 officers in the present Army were in civilian life only a short time ago, and the community of officers in the Army is therefore nearly a cross section of the general public. However, the statement is made usually with respect to the regular officers of the Army and Navy, men who have made military matters their profession.

I have been working very closely indeed with a large number of those officers for three years now. Prior to that time I had had long association with the engineers in the United States, with college faculties, and with businessmen. In every one of these groups, I have met individuals whose receptivity to new ideas was absolutely zero. I shall not single out any particular group for comment, but in every one of these great sections of our population in this country I have been struck at times by an unwillingness to recognize the changing nature of the technical world to an extent that annoyed me exceedingly. I have seen it among college teachers and in groups of engineers, and I have certainly seen it among businessmen. I have also seen the same thing among military officers.

I say to you categorically, however, and I think I am in a position to know, that the men who lead the Army and Navy of the United States in this fight are no less

open to new ideas than is the general public of the United States; and if we as a country are overconservative and disinclined to try new things, then I do not know what the words mean. True, the officers who have seen service are hard-boiled. They have a keen appreciation of what will and will not work—at sea under difficult conditions and various types of weather, on land in the dust and mud of battle. They are intensely practical men, and at the present time they are exceedingly busy men, but they are not reactionary. In two and one-half years of close association with them in the development of new weapons, I have as yet to see the instance where an idea or a device which has come to the attention of the OSRD and which in my opinion had outstanding merit was turned down arbitrarily and blocked permanently by any military officer or any group of military officers. The merit of new ideas has to be proved. Ideas have to go through their growing periods and meet their stresses. This has to occur in business in time of peace and in military affairs in time of war, but the atmosphere is no more hostile in one case than it is in the other.

OTHER DEVELOPMENT AGENCIES

But to return to civilian organizations, there are several aspects of the development of new weapons which very definitely do not come under the control of OSRD, although the council of OSRD functions in an advisory capacity in order to provide a unitary approach to problems of common interest and to prevent overlap and duplication.

Notable in this connection is the National Advisory Committee for Aeronautics. I do not need to trace the position of this organization, as it has been done elsewhere. Founded by Congress over 25 years ago, it has a long and notable record of accomplishment. Inasmuch as the problems of flight are being attacked adequately by the NACA, they are not again attacked by the NDRC, although the latter often carries on work on military devices which become incorporated in airplanes. It is a fortunate thing for the United States that it has had for many years an active research organization in the field of aeronautics. It has worked in close collaboration with the Army and Navy and with industry. A short time ago there was a great deal of discussion as to whether American airplanes were comparable with those of the enemy. Since the records have been coming in from England, Africa, and the South Pacific, this discussion seems to have become resolved.

Because of the interaction of many factors, but particularly because of the fact that we have long had an active independent research organization, working on a basis of excellent interchange with the Army and Navy, and supplying the fundamental basis for the advance design of aircraft, this country has not lagged in the subject, and its position at the present time can best be understood by reading the recent comments of General Arnold, commanding general of the Army Air Forces.

The ideas that finally become incorporated in new military devices originate in a great variety of ways. Many of them come directly from officers of the armed services, and this is increasingly true, as our combat indicates to officers at the front the needs and opportunities. Some ideas come from the scientific and military groups assembled as sections of NDRC as a result of their conferences and discussions. A large number are submitted by the general public. These require a great deal of review, for the percentage of valuable suggestions coming in this spontaneous way will always be small. This review is provided by the National Inventors Council, located in the Department of Commerce. Again, I do not need to review the manner in which this organization operates in order to bring to bear on suggestions from the public the judgment of competent scientists and engineers, and to forward to the armed services for their review the interesting ideas that emerge. There are, however, one or two points in regard to their work upon which I feel it is well to elaborate.

It should be emphasized that the NIC is the official reviewing agency, and that its function is fully performed when it has brought a valuable suggestion to the appropriate attention in the armed services. At the same time it is essential to emphasize that the OSRD does not have the duty of reviewing suggestions submitted by the general public. When the armed services find that an idea warrants development, they may turn to the OSRD in order to have such development performed. Research and development are the functions of OSRD, and it attempts to stay strictly within those bounds. However, the sections that are making plans for the development of new weapons receive many ideas from the members of the group itself, from engineers and scientific men working with contractors who are carrying out research under the supervision of the section, from the officers and men of the armed services, and through the armed services from the Inventors Council.

Unfortunately, the independent inventor is at a very considerable disadvantage when it comes to the matter of making valuable suggestions in connection with military devices. In the nature of things, he cannot be told the entire state of the art to which he is attempting to contribute, so that he works very largely in the dark. This is unfortunate, for the same reasoning is unduly gone through over and over, but it is inevitable in view of the necessity for security. When a man who has placed a great deal of effort on the development of an idea finally submits it, he would like to know whether his idea is new, whether it is considered valuable, and especially, he would like to know if it is being used. Yet in general he cannot be told; in fact, he cannot be told unless he occupies a position in which he is entitled to secret and confidential information in the field of this inquiry. If this principle were not strictly adhered to, the enemy might find out a great deal by simply putting in sugges-

tions and thus learning the general state of the art and the status of development of various military weapons.

I mention this because I believe there has been a great deal of misunderstanding on the matter, and many individuals in the United States have become distinctly annoyed because they were not told of the outcome of review when they made suggestions. It is strange that this situation is not more fully appreciated than it is at the present time. As an example, there was recently published in a prominent magazine an article which described in detail a military device which had been submitted to the armed services, and the article complained bitterly that no serious attention was paid to the suggestion. As a matter of fact, the inventor in this particular instance had visited me personally and described his device. At the time he described it to me, I knew that a better device than the one he suggested was already in use. This I could not tell him. Of course, if his suggestion really had been new and highly valuable, the publication of it with full details would have been of great service to the enemy.

There is another phase of the work of scientists and engineers on developmental matters which also needs to be mentioned. There are broad problems of substitute and strategic materials, and many technical questions involved in the reorientation of industry to the war effort. The development of substitute materials and substitute processes is of enormous significance as the war proceeds. The task of conducting research and development along these lines is not within the scope of OSRD, the activities of which are directed to the development of new weapons and their methods of utilization. On the other hand, the War Production Board has long been deeply concerned with these very matters. In some of its approaches to the problems of materials it has been strongly supported by the National Research Council with scientific and technical advice. Recently, a new office within the WPB has been formed, called the Office of Production Research and Development, and Doctor Harvey N. Davis, president of Stevens Institute of Technology, Hoboken, N. J., is director of this new office.

Many auxiliary problems arise in connection with the technical and scientific effort, and prominent among these is the problem of trained personnel. Fortunately, we have had for a long time now the Roster of Scientific and Specialized Personnel, conducted under the chairmanship of Doctor Leonard Carmichael, president of Tufts College, and his office is now attached to the War Manpower Commission, where it is rendering excellent service.

The rapid survey of the organizational set-up would not be complete, however, without final mention of the National Academy of Sciences and the National Research Council. The National Academy of Sciences was formed at the time of the Civil War and operates under Congressional charter. It is charged with the broad duty of advising agencies of government with regard to their scientific and technical problems. Doctor Frank B. Jewett, president of the Academy, has recently described in some detail the enormous burden which has been carried by the Academy and Council in the performance of this obligation. The OSRD leans on the Academy and Council for scientific and technical advice on many matters. Notably in the medical and metallurgical fields, the organization of the NRC has provided committees of eminent men who have advised continuously and effectively on programs in these fields.

To one who has not worked closely with the governmental organization for the conduct of research and development in time of war, this rapid survey of the organization may seem to indicate a great deal of complexity. It is true that it is complicated, but research and development are themselves necessarily complex. However, the various aspects of the over-all problem now are provided for adequately by the organizations that are operating in the field, and these are tied together as closely as necessary for co-operation by the council of OSRD. The armed services themselves are concerned with procurement, installation, testing, and use. The review of suggestions, the conduct of research and development in the aeronautical field, in the matter of substitute materials, and directly in the development of new weapons are provided for by appropriate groups.

RESULTS OF RESEARCH AND DEVELOPMENT

But what of results? In wartime the work of the laboratory is meaningless unless it finds its way into the field of action. The most tangible expression of the success of scientific effort in the present war is to be found in the attitudes of the armed services. Both the Secretary of War and the Secretary of the Navy have indicated to me their satisfaction over what joint efforts have accomplished in terms of operations. At the close of the last fiscal year, the War Department pointed out that it had placed orders amounting to approximately $560,000,000 for items developed by one section alone of the NDRC. As a result of a new process for making an important military material developed by another section, the Army placed orders for plant and product amounting to about $270,000,000. In this instance there was an anticipated initial saving of $100,000,000 in plant-construction costs and additional savings of many thousands of dollars a day in operating costs, as compared with previous methods.

These figures are now some months old, and a great deal has happened since then. When the story can be told, it will be dramatic, and it will reflect the vigorous efforts of a great group of men, employing the best of teamwork in the common cause. Until then we cannot talk of results. The evidence accumulates rapidly, however, that the devices being developed by American scientists and engineers will play an important part in bringing the war to successful conclusion in a shorter time than might otherwise have been the case.